s

Family Name	
Given Names	
Student Number	
Teaching Period	Semester 2, 2015

FINAL EXAMINATION	DURATION
ENG224 – Electrical Machines and Power Systems	Reading Time: **10** minutes Writing Time: **180** minutes

INSTRUCTIONS TO CANDIDATES

1. Read questions carefully and answer them all.
2. Questions are not of equal value.
3. Show all diagrams, units and working out as part of your complete answer.
4. Units are important. If you do not mention the unit of a quantity, you will lose some credit.

EXAM CONDITIONS

This is a CLOSED BOOK examination
Any non-programmable calculator is permitted
No handwritten notes are permitted
No dictionaries are permitted
Answer on the supplied examination material/s only

ADDITIONAL AUTHORISED MATERIALS	EXAMINATION MATERIALS TO BE SUPPLIED
No additional printed material is permitted	1 x 20 Page Book

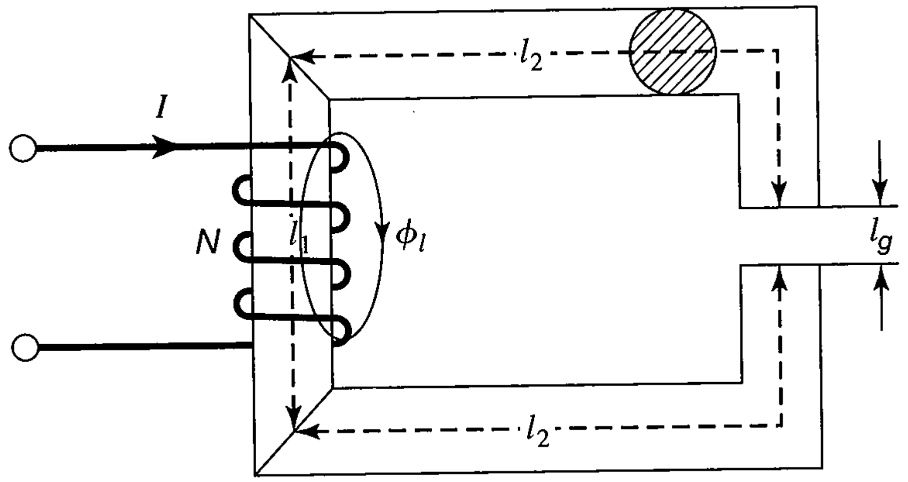
THIS EXAMINATION IS PRINTED DOUBLE-SIDED.

THIS PAGE HAS BEEN INTENTIONALLY LEFT BLANK.

QUESTION 1 **(20 marks)**

Figure 1.1 shows a magnetic circuit, the core of which is made up of cast steel with a B-H curve shown in Figure 1.2.

Q1.1. Calculate the required exciting current, I, to produce an air gap flux density is 1.1 Tesla. (15 marks)
Q1.2. Calculate the self-inductance of this coil. (2 marks)
Q1.3. Calculate the Leakage inductance of this coil. (2 marks)
Q1.4. What will be the mutual inductance? (1 mark)



$l_1 = 10$ cm
$l_2 = 20$ cm
$l_g = 1.0$ mm
$N = 100$
$\phi_l = 0.1$ mWb
$A = 5$ cm^2

Figure 1.1 Magnetic circuit for Question 1

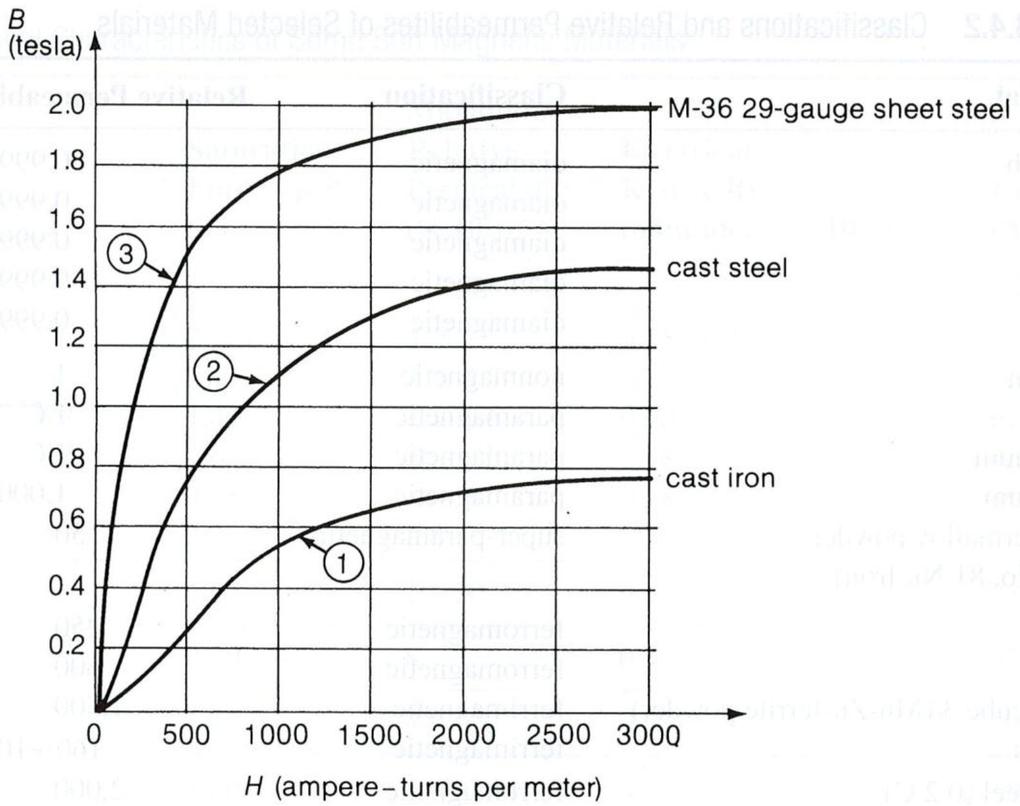


Figure 1.2 DC magnetization curves for Question 1.

QUESTION 2 **(15 marks)**

A three phase induction motor draws a starting current which is five times the full load current with direct on line starting, while developing twice the full load torque.

Q2.1. Based on the two facts that starting current is proportional to the applied voltage and that the starting torque is proportional to the square of the applied voltage, determine voltage (as a per cent of rated voltage) required to obtain a starting torque equalling the full load torque. (10 marks)

Q2.2. What is the starting current under this condition? (5 marks)

QUESTION 3 **(20 marks)**

Q3.1 What are the advantages of shell type transformers over core type?

Q3.2 Why are ac machine cores laminated but dc machine cores are not?

Q3.3 Why starting currents of dc machines are very large compared to their current ratings?

Q3.4 What is transformer inrush current?

Q3.5 Can only two pieces of identical single phase transformers be used to supply a three phase load? Discuss the issue.

Q3.6 In starting a separately excited dc motor, the field circuit is energized before the armature circuit. Explain why this is done.

Q3.7 Why are alternators in an interconnected power system run at a single speed?

Q3.8 What per cent of total losses in a dc motor are due to hysteresis and eddy current? Discuss.

Q3.9 Induction machines are very commonly used in industries. Why not induction generators?

Q3.10 When a 240 volt 50 Hz 4 pole induction motor operates at 1450 rpm, what would be the rotor circuit frequency?

(2 marks each)

QUESTION 4 **(5 marks)**

A three phase star connected 6.25 kVA 220 volt synchronous generator has a reactance of 8.4 ohms per phase.

Q4.1 Using the generator ratings as base quantities, determine the per unit reactance. (3 marks)

Q4.2 Determine the reactance value as a per unit quantity for a 230 volt 7.5 kVA system. (2 marks)

FORMULAS

(Symbols have their usual meanings in the context of the particular formula)

MAGNETIC CIRCUITS: $L = \lambda/i = N^2/\Re = \mu N^2 A/d$; $Ni = \sum H\ell = \varphi\Re$;

$B = \mu H = \mu Ni/\ell$; $\mu = \mu_r \mu_0$; $\Re = \ell/\mu A$

TRANSFORMERS: $\frac{V_1}{V_2} = \frac{I_2}{I_I} = \frac{N_1}{N_2}$; $Z_1 = \left(\frac{N_1}{N_2}\right)^2 Z_2$; $R_c^{'} = \frac{V_{oc}}{I_{oc}\cos\theta}$; $X_m = \frac{V_{oc}}{I_{oc}\sin\theta}$;

$\cos\theta = \frac{P_{oc}}{V_{oc} I_{oc}}$; $\eta = \frac{V_2^{'} I_2^{'} \cos\theta}{V_2^{'} I_2^{'} \cos\theta + P_c + R_{eq}^{'} (I_2^{'})^2} \times 100\%$

$$\eta_{AD} = \frac{\text{Energy output over 24 hours}}{\text{Energy input over 24 hours}} \times 100\%$$

$$\text{Regulation} = \frac{\text{No load voltage} - \text{Full load voltage}}{\text{Full load voltage}} \times 100$$

INDUCTION MACHINES: (Torque and power are given on a per phase basis)

$n = 120\frac{f}{p}$; $s = \frac{(n_s - n)}{n_s}$; $f_2 = sf_1$; $E_{rms} = 4.44f\, N_{ph}\, \varphi_p\, K_w$

$V_{th} = \frac{X_m}{\sqrt{R_1^2 + (X_1 + X_m)^2}} V_1$; $R_{th} \cong \left(\frac{X_m}{X_1 + X_m}\right)^2 R_1$ $X_{th} \cong X_1$

$P_{mech} = T_{mech}\, \omega_{mech} = (1-s)P_{air\_gap}$; Ideal Efficiency = 1-s;

$T_{mech} = \frac{1}{\omega_s} I_2'^2 \frac{R_2'}{s} = \frac{1}{\omega_s} \frac{V_{th}^2}{(R_{th} + R_2'/s)^2 + (X_{th} + X_2')^2} \frac{R_2'}{s}$; $P_{air\_gap} = I_2'^2 \frac{R_2'}{s}$

$s_{T\max} = \frac{R_2'}{\sqrt{R_{th}^2 + (X_{th} + X_2')^2}}$; $T_{\max} = \frac{1}{2\omega_s} \frac{V_{th}^2}{R_{th} + \sqrt{R_{th}^2 + (X_{th} + X_2')^2}}$

DC MACHINES: $K_a = \frac{Zp}{2\pi a}$; $E_a = K_a \varphi\omega$; $T = K_a \varphi I_a$; $P_{out} = E_a I_a = T\omega$; La=p wound.

ALTERNATORS: $E_f \propto I_f$ $E_f = V_t + jI_a X_s$ $E_f = V_t + I_a R_a + jI_d X_d + jI_q X_q$

$P = \frac{|V_t||E_f|}{|Z_s|}\cos(\theta_s - \delta) - \frac{|V_t|^2}{|Z_s|}\cos\theta_s$ $Q = \frac{|V_t||E_f|}{|Z_s|}\sin(\theta_s - \delta) - \frac{|V_t|^2}{|Z_s|}\cos\theta_s$

$E_f = V_t\cos\delta \pm I_d X_d$, $I_a = |I_q| - j|I_d|$ and $V_t = |V_t|\angle{-\delta}$

$P = \frac{|V_t||E_f|}{|X_d|}\sin\delta + \frac{|V_t|^2 (X_d - X_q)}{2X_d X_q}\sin 2\delta$ $Q = \frac{|V_t||E_f|}{|X_d|}\cos\delta + |V_t|^2 \left|\frac{\sin^2\delta}{X_q} + \frac{\cos^2\delta}{X_d}\right|$

OTHERS: $S = \sqrt{3} V_L I_L$; $Z_{pu} = \frac{Z_{ohm}}{Z_{base}}$; $Z_{base} = \frac{(kV_{base})^2}{MVA_{base}}$;

$S_{pu} = kV_{pu}\, kA_{pu}$ (no √**3**); $kA_{pu} = \frac{MVA_b}{\sqrt{3}\, kVA_b}$; $Z_{pu2} = Z_{pu1} \times \frac{S_{base2}}{S_{base1}} \times \frac{kV_{base1}^2}{kV_{base2}^2}$